The *Journal of Cotton Science 24:34–43 (2020)*
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ENGINEERING AND GINNING

Development of the Cotton Gin

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ABSTRACT

Cotton fiber was first used in 6000 B.C. The two New World cotton species that are most of today's production include *G. hirsutum* (Upland) and *G. barbadense* (Extra Long Staple [ELS]). The first cotton gin existed by the 5th century A.D (single-roller gin). The next development was the churka gin (double-roller gin) which ginned cotton five times faster than the single-roller gin. The churka gin was widely used in North America by 1750 and ginned both Upland and Sea Island (ELS) cotton. The spike-tooth cotton gin was developed by Eli Whitney in 1794. Hodgen Holmes developed a continuous flow gin with toothed saw blades in 1796. These were a different concept than the double-roller gins. Holmes' saw gin dominated the industry for Upland cotton (and still does), whereas double-roller gin use continued for Sea Island cotton. In 1840, Fones McCarthy developed a reciprocating-knife roller gin. The saw gin had a significantly higher ginning capacity than the McCarthy gin, so it was used with Upland cotton and the McCarthy roller gin was used with Sea Island cotton to preserve the long-staple cotton's quality. Sea Island production ceased in 1923 because of the boll weevil, but Pima (ELS) cotton had developed by this time in the Southwest, so roller gin use continued. In 1963, a rotary-knife roller gin was developed that ginned at five times the rate of a reciprocating-knife gin. A high-speed roller gin was developed in 2005 with a ginning capacity, on a per-width basis, comparable to modern-day saw gins.

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THE BEGINNINGS OF GINNING

Ginning, in its simplest context, refers to the process of separating cotton fibers from the seeds. The first cultivation of cotton and use of cotton fiber are lost in the mists of time. The first cotton producer had to remove the fiber from the seed to utilize the fiber (Hughs and Holt, 2015). Although it is possible to remove the fiber from the seed with the thumb and forefinger, it is a slow and laborious process and probably quickly led to the invention of the first cotton gin (Lakwete, 2003). The term "gin" might be a contraction of the word "engine" and is applied to any mechanical device that applies force to remove cotton fiber (lint) from cottonseed (Vandergriff, 1997).

The development of the cotton gin was dependent on the domestication and development of the cotton plant and the utilization of its fiber. Archaeological artifacts proving the use of cotton fiber date from the Neolithic period (approximately 6000 B.C.) and were found in what is now known as Pakistan (Giband et al., 2010). Other ancient textiles have also been found in Mexico, Peru, and the Indus Valley that today lies in Pakistan and northern India. Of the more than 50 species of the genus *Gossypium*, there are four species that produce spinnable fibers of interest to the textile industry. Two species are from the Old World, *G. arboreum* L. and *G. herbaceum* L., and two species are from the New World, *G. hirsutum* L. and *G. barbadense* L. It is these four species that are commonly referred to when speaking of the world's cotton industry. The varieties developed from the two Old World species and the *G. hirsutum* New World species have fuzzy seed coats when the useable fibers are removed (ginned) and are commercially known as short-staple, green seed, or Upland cottons (Lakwete, 2003). The *G. barbadense* extra-long staple (ELS) varieties have a naked or black seed after useable fibers are ginned and are commercially known as Pima or American-Egyptian cottons. (Sea Island cottons are also from the *G. barbadense* species but are not widely grown commercially.) A characteristic of Upland cotton is that the strength of fiber attachment to the seed is significantly greater than that of Pima cotton (Lyengar,

1954). This strength of attachment difference between Pima and Upland varieties has had a dramatic impact on the development of the cotton gin.

The first cotton gin existed by at least the fifth century A.D. and likely existed long before that but would be difficult to identify by archeologists as a gin due to its construction (Lakwete, 2003). This first gin existed in both the Old and the New worlds and was known as a single-roller gin. It consisted of two separate parts: a small roller approximately 30-cm (12-in) long and no more than 1.6 cm (0.625 in) in diameter (to keep from crushing seeds), and a separate flat base approximately 13-cm (5-in) wide and 20- to 25-cm (8–10-in) long. The roller was made from some type of metal or hard wood and the base was a flat stone or piece of wood. The ginner grasped both ends of the roller and rolled it over seed cotton lying on the base to pinch the seed apart from the lint much like a baker using a rolling pin to roll out dough. Skill, as well as strength, was required to continually remove the seed from the fiber without crushing the seed (Bennett, 1960; Hughs and Holt, 2015). This type of cotton gin has persisted to the modern day for certain traditional and ceremonial uses. (The authors watched a woman in Mali, West Africa, in 2007 use a single-roller gin to gin a fuzzy-seeded variety of cotton.)

The next type of gin developed is generally called the churka gin. It is not known when this gin was first developed but it has existed for centuries in various forms in China, India, Southeast Asia, and the Middle East (Bennett, 1960; Lakwete, 2003). This gin in its various forms consisted of two small-diameter rollers that rotated simultaneously in opposite directions and is called a double-roller gin (Fig. 1). The rollers were roughly 30-cm (12-in) long, made of some combination of wood or metal, and powered by either one or two hand cranks. The two rollers were wedged together by the ginner into a vertical frame and were counter rotated. As the rollers turned, they pulled the cotton fibers between them while pinching the seed off the fiber tuft. The seed could not pass through the tightly wedged rotating rollers and so dropped away as the fiber passed between the two rollers. This action effectively separated the fiber from the seed (Hughs and Holt, 2015). The churka gin had an average fiber turnout of 2.3 kg (5 lb) of fiber per day, which was five times that of the single-roller gin (Lakwete, 2003). This double-roller gin was harder to make than the single-roller gin but due to its higher ginning rate was probably the dominate method of ginning cotton in medieval cotton production.

Figure 1. Churka gin and operator (Anonymous, copyright unknown).

The first recorded beginnings of modern cotton production in the New World began with the Spanish experimental planting of cotton in Florida in 1556 and the settling of the Virginia Colony in North America by the British in 1607. The Virginia colonists probably received cottonseed from the British East India Company (probably the Old World species *Gossypium arboretum* or *G. herbaceum)* before departing for the voyage to America (Lakwete, 2003; May and Lege, 1999; Smith et al., 1999). Cotton production slowly spread from Virginia to other colonies and was grown mainly for domestic consumption until approximately 1770. At this time American colonists started exporting larger amounts of ginned Upland cotton fiber to Great Britain. It was thought, until recently, that all Upland cotton ginned prior to Eli Whitney patenting a cotton gin in 1794 was ginned by hand but such was not the case. Along with the cottonseed brought from the British East India Company, the colonists probably brought some form of the churka or double-roller gin to separate the cotton fiber from the seed (Lakwete, 2003).

The early history of ginning machines in the American colonies is not clear, but there is enough documented evidence to indicate that churka-type double-roller gins were used on the North American mainland by 1750 and probably before (Lakwete, 2003). Variations and improvements of the churka that were either human, water, or animal powered were the types of gins that were used in North America up until and beyond the date of Eli Whitney filing his patent for a new ginning principle in the U.S. in 1794. The cotton ginned prior to approximately 1786 on these double-roller gins were fuzzy-seeded Upland varieties and not the black-seeded Sea Island cotton. Sea Island cotton was first planted on St. Simons Island off the coast of Georgia in 1785,

long after Upland cotton production was established and ginned in the colonies (Porcher and Fick, 2005).

Prior to the American Revolution, England was the market for U.S raw cotton and from which the U.S. then imported finished textiles. Textile imports from England were stopped during the Revolutionary War (1775-1783), and cotton acreage expanded to meet U.S. domestic textile needs. Large quantities of homespun textiles were produced and small textile factories were built. When the war was over, the relationship between the U.S. and England had changed from a colony that supplied raw materials to the mother country for finished goods to partners in world trade (Anthony and Mayfield, 1994; Lakwete, 2003). Richard Arkwright invented the water-driven spinning frame in 1769, which greatly improved yarn quality and production speed for British spinners, helping to usher in the industrial revolution at the end of the 18th century. Other similar textile-processing improvements significantly boosted Great Britain's need for raw cotton for its own industry at a time when America needed trading partners. Finally, as a young country, America was building and expanding its own textile industry and participating in world trade as part of its own economic health and growth.

THE EARLY SAW GIN

The stage was set for Eli Whitney's invention and patenting of the spike-tooth cotton gin in 1794 and for Hodgen Holmes's patent of a saw-tooth cotton gin in 1796. Whitney's and Holmes's patents were signed by George Washington on 14 March 1794 and 12 May 1796, respectively (Moore, 1977; Lakwete, 2003). Whitney's gin removed the fibers from the seed by means of small spikes driven into a wooden cylinder (Fig. 2). The spikes engaged the fibers and pulled them through narrow slots in a metal bar at the back of a seed cotton roll box. The slots, too narrow for the seeds to pass through, retained the seeds and allowed the fiber to be pulled free. A brush cylinder behind the slotted bar removed the fibers from the spikes. From patent descriptions, the ginning cylinder was from 15 to 23 cm (6-9 in) in diameter and 0.6 to 1.5 m (2-5 ft) in length and had a wood core studded with coarse, sharpened iron spikes arranged in annular rows spaced apart by approximately the size of a cottonseed (Lakwete, 2003). Whitney's patent was not another improvement on existing double-roll pinch gins but a completely different concept that significantly increased ginning capacity. In a 1793 letter to Thomas Jefferson, Whitney described his machine's performance (Mirsky and Nevins, 1952):

> It is turned by hand, and requires the strength of one man to keep it in constant motion. It is the stated task of one Negro to clean fifty weight (I mean fifty lbs. after it is separated from the seed) of the green-seed cotton per day. This task he usually completes by 1:00 o'clock in the afternoon. He is paid so much per pound for all he cleans over and above his task and to ten or fifteen days successively he had cleaned from sixty to eighty weight per day and left work every day before sunset.

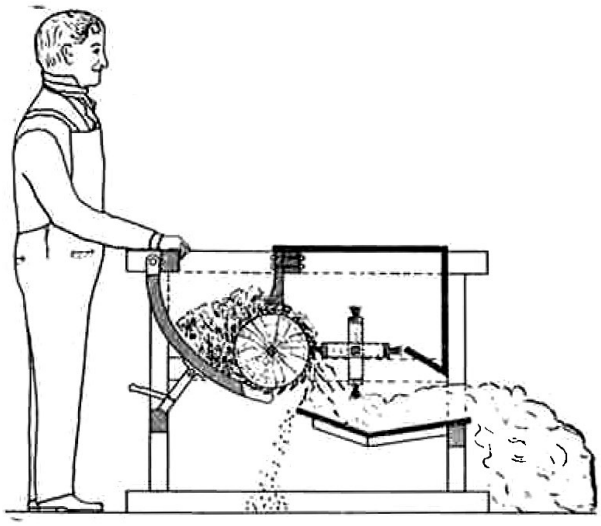

Figure 2. Eli Whitney's cotton gin (taken from Saw and Toothed Cotton Ginning Developments by Charles A. Bennett).

Whitney's gin as patented had two weaknesses: (1) the sharpened spikes tended to loosen from the wood core and fall out, and (2) it was a batch process. The ginner filled the roll box with seed cotton and cranked the cylinder until all the seed was cleaned of fiber. Then the ginner would stop turning the cylinder and dig the cleaned seed out of the roll box before filling it again with seed cotton and repeating the process. Holmes's patent, while similar, had three major improvements over Whitney's: (1) spikes in a wooden core were replaced with circular saws that were much more durable, (2) the slotted bar was replaced by flat-iron ribs, and (3) the bottom of the roll box was opened up for the continuous discharge of ginned seed, permitting continuous operation as opposed to Whitney's batch operation (Fig. 3) (Moore, 1977).

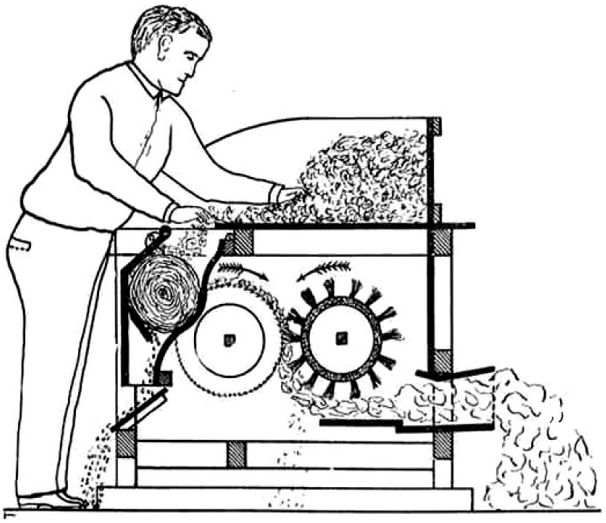

Figure 3. Hodgen Holmes cotton gin (taken from Saw and Toothed Cotton Ginning Developments by Charles A. Bennett).

Whitney's and Holmes' patents are matters of public record, but some believe there is strong evidence that Whitney was not the original source of the ginning principle that he patented (Buchele and Mayfield, 2016). Buchele and Mayfield (2016) argued that Hodgen Holmes might have been granted a caveat of invention (these were in force for five years) on 14 March 1789; in addition, South Carolina folklore states Holmes was the inventor of a rip-saw-toothed cotton gin prior to Whitney's patent. Other evidence such as early newspaper ads and shipping records of the export and sale of significant quantities of ginned green-seeded cotton are indicators that some ginning method other than double roller gins was used to gin U.S. cotton. Regardless of who originated the basic principle of the saw gin, it is Holmes' basic patented design of a continuous-flow gin utilizing toothed saw blades that dominated the ginning industry as the American cotton industry grew and the country moved West. Upland cottons dominated cotton production inland and became the primary cotton grown, with Sea Island cotton production primarily confined to coastal areas. As a result, the older double-roller gin designs lessened in use for Upland cottons over time and were primarily used for the higher quality and longer staple Sea Island cottons (Hughs and Holt, 2015).

THE EARLY ROLLER GIN

Early roller gins in the U.S. were improved versions of the double-roller churka type. The double-roller gins in use by the long-staple Sea Island cotton planters in 1840 could only gin approximately 11 kg (25 lb) of long-staple fiber in a day per stand (Lakwete, 2003). The saw gin could gin much faster, but it tended to damage the staple length, whereas the double-roller gins were slower, but better preserved fiber length and therefore continued to be used on the longer staple Sea Island cottons.

The first major modern change in roller-gin design occurred in 1840 with the invention of the reciprocating-knife principle by Fones McCarthy of Demopolis, AL (Alberson and Stedronsky, 1964; Gillum, 1985; Lakwete, 2003; Porcher and Fick, 2005). The McCarthy reciprocating-knife roller gin basically consisted of a large single roller [10 cm (4 in) or more in diameter] covered with leather, a stationary knife that rode with some pressure against the roller, and a reciprocating knife that pushed up and down on the seed to separate it from the fiber (Fig. 4). The operation of the McCarthy gin removed the fiber from the seed by (1) pushing the seed cotton against the revolving roller, (2) pulling the fiber under the stationary knife (the seed could not go under), and (3) the reciprocating knife pushing on the seed until it was entirely separated from its lint and the seed fell away (Hughs and Holt, 2015). The original McCarthy gin could process 68 to 91 kg (150-200 lb) of fiber per day with a single gin stand. McCarthy originally intended the reciprocating-knife roller gin for Upland cottons. Although the McCarthy reciprocating-knife roller gin better preserved fiber length than the saw gin, the saw gin had a significantly higher ginning capacity. Sea Island cotton growers adopted the higher-capacity one-operator McCarthy gin that could replace several older-design double-roller gins and their operators.

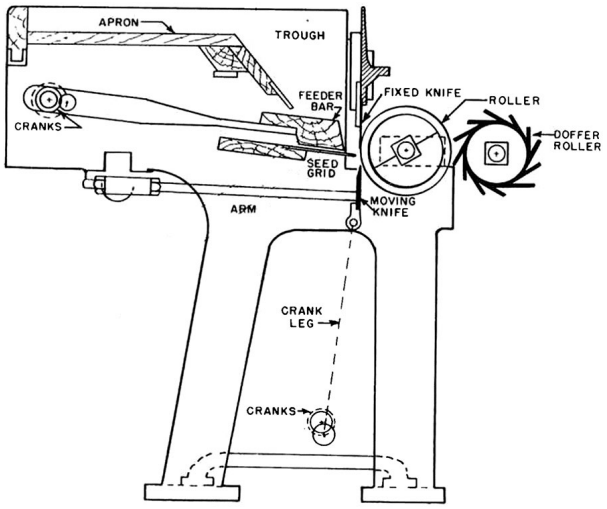

Figure 4. Fones McCarthy reciprocating-knife roller gin (taken from Cotton by David D. Fang and Richard G. Percy).

As a result of the differences in capacity and ginning performance of the two basic gin designs, the reciprocating-knife roller gin primarily was used to gin ELS Sea Island cotton (later American-Egyptian or Pima cottons) and the saw gin was used to gin Upland cotton from the 1840s through most of the 20th century. Because Upland cotton varieties became the predominate cottons grown in the early 1800s and Sea Island cottons comprised a small percentage of U.S. cotton grown, the saw gin quickly became the predominate gin type of the U.S. ginning industry.

DEVELOPMENT OF MODERN SAW GINNING SYSTEMS

For many years after 1796, ginning was simply another farm operation performed at the plantation after harvesting had been completed. These plantation gins were predominately one hand-fed saw gin that was part of a simple ginning system that generally included a two-story building with the saw-gin stand on the second floor (Fig. 5) (Bennett, 1962; Hughs et al., 2008). These early gins were generally animal or water powered with seed cotton manually carried to the gin stand, and the ginned lint then manually carried from a blow room to a separately located animal-powered wooden screw press where bales were pressed and manually bagged. By the 1880s, mechanical screw presses, gin feeders, and pneumatic cotton-handling systems had reduced the need for manual labor and enabled several gin stands to operate simultaneously as a single ginnery (Hughs and Holt, 2015). Many plantations could not afford these more complex ginning systems and so custom ginning operations were established in communities to serve more than one cotton grower. By the close of the 19th century the plantation gin was essentially a thing of the past and the beginnings of the modern cotton ginning industry had arisen.

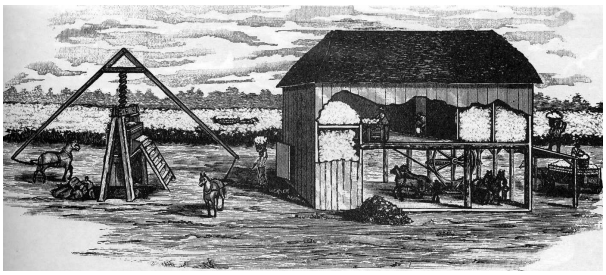

Figure 5. Early plantation saw ginning system (taken from Saw and Toothed Cotton Ginning Developments by Charles A. Bennett).

By the 1920s, ginning systems similar to that shown in Fig. 6 were common and were centrally located in cotton growing areas to serve surrounding growers. The cotton ginned by these cotton gins was still hand-picked, but once the cotton arrived at the gin, a minimal amount of manual labor was required to process the seed cotton into baled lint compared to cotton gins of the previous century. Seed cotton cleaning machines were added prior to the gin stand to remove leaves, sticks, burs, and soil brought in from the field before ginning. These ginneries were now powered by a single engine or motor that powered the entire ginnery via a long shaft running the length of the facility and belts connected to the individual machines. These line-shaft gins had multiple gin stands and were capable of processing from four to six 227-kg (500-lb) cotton bales per hour on well harvested and dry cotton (Bennett and Gerdes, 1935).

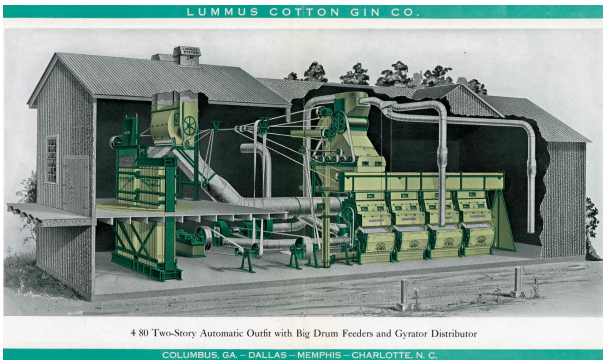

Figure 6. 1920s cotton ginning system (taken from 100 Years of Cotton Production, Harvesting, and Ginning Systems Engineering: 1907-2007 by S. E. Hughs, T. D. Valco, and J. R. Williford).

In the early days of ginning, cotton was carefully hand-picked by workers who had a direct interest in the crop and was relatively clean. However, as cotton production increased, it became necessary to employ additional hand-harvesting labor. These additional labor requirements led to faster and rougher harvesting, including hand snapping and hand stripping, with greatly increased foreign matter and moisture content in the harvested seed cotton (Moore and Merkel, 1953). Seed cotton dryers (tower dryers) were developed by the U.S. Department of Agriculture, Agriculture Research Service (USDA-ARS) and adopted by the ginning industry in the 1930s to reduce the moisture content of the rougher harvested seed cotton and to improve the performance of the seed-cotton cleaners at handling and cleaning damp cotton (Fig. 7).

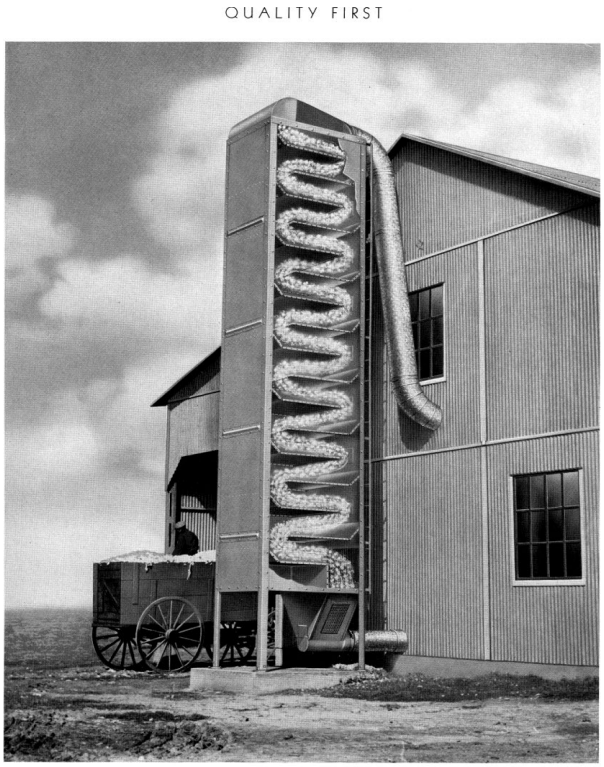

Figure 7. Illustration of early tower dryer (Anonymous, copyright unknown).

Additional changes were made to the saw ginning system with the development of mechanical stripper harvesting before the 1940s and mechanical pickers that began to be adopted by the cotton industry shortly after World War II (Hughs et al., 2008; Mayfield et al., 1991; Moore, 1977). From the 1940s until the 1960s the increased use and speed of mechanical harvesting significantly shortened the harvest season and caused a demand for higher capacity ginning equipment and increased drying and cleaning during the ginning process. By the 1960s most cotton gins had at least two stages of drying, several stages of seed cotton cleaning, and at least two stages of lint cleaning after the saw gin stand and before the bale press (Fig. 8).

In the latter part of the 20th century, cotton trailers were abandoned for stand-alone rectangular cotton modules, which allowed farmers to harvest their cotton in a more timely manner and made the transport of seed cotton long distances to the gin more economical. Today the cotton industry is transitioning into even larger and faster cotton pickers with modules formed on-board (Hughs and Holt, 2015). These developments have continued to pressure the ginning industry for even higher capacity cotton gins. Figure 9 shows a typical cross section of a high-capacity saw ginnery for processing machine-picked cotton with unloading (module feeder, unloading hopper, rock catcher), seed cotton drying and cleaning (tower dryer, hot-air cleaner, stick machine, inclined cleaner, and extractor feeder), saw-gin stand, lint cleaning (centrifugal air and saw-type lint cleaners), and bale packaging (battery condenser and bale press) all connected by pneumatic conveying systems. A typical saw-gin facility for processing machine-stripped cotton would look similar except that it would have additional seed cotton cleaning machinery (horizontal pre-cleaner and two stick machines) as shown in Fig. 10 to handle the additional cotton trash brought in from the field. Processing rates of today's saw ginneries range from 20 to more than 80 bales per hour [each bale weighing 218 kg (480 lb)]. Ginning has historically evolved in response to changing cotton varieties and production and harvest practices. This process is still going on today and, even though almost no two modern cotton gins are alike in their equipment makeup and layout, Figs. 9 and 10 are representative of current U.S. saw gin plants in order and sequence of specific types of individual machines.

Figure 8. Typical 1960s saw ginning system (Anonymous, copyright unknown).

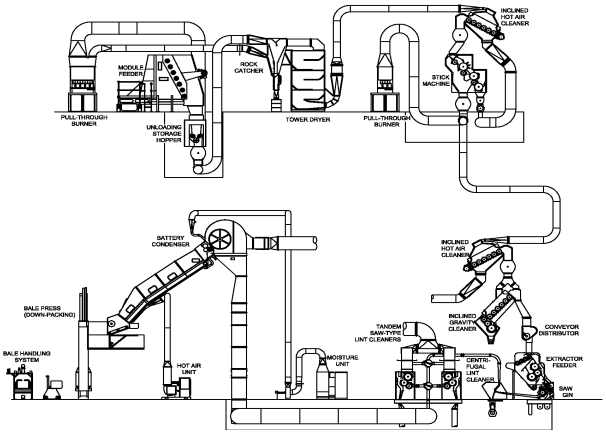

Figure 9. Typical current saw ginning system for machine-picked cotton (courtesy of Ross Rutherford, Lummus Corporation).

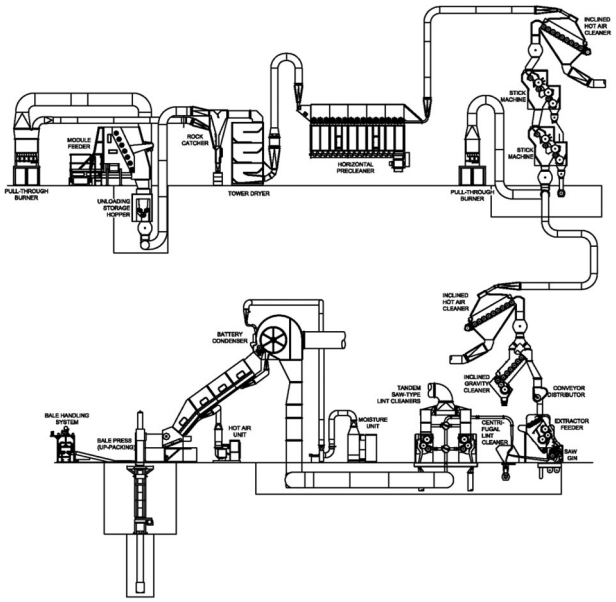

Figure 10. Typical saw ginning system for machine-stripped cotton (courtesy of Ross Rutherford, Lummus Corporation).

DEVELOPMENT OF MODERN ROLLER GINNING SYSTEMS

The reciprocating-knife roller gin developed into the gin of choice for long-staple Sea Island cottons after McCarthy's patent in 1840. Following this initial patent there were several inventors who patented improvements on the McCarthy gin and other designs of roller-type gins (Porcher and Fick, 2005). Fones McCarthy himself continued to improve on his original design with patents in his name as late as 1867 (Bennett, 1960). Also, duplex-roller gins were developed in the 1800s and early 1900s that were essentially two back-to-back McCarthy roller gin stands with some modifications. None of the competing inventors for long-staple cotton gins, whether single- or double-roller, were ultimately successful against the McCarthy-type roller gin. The McCarthy reciprocating-knife roller gin revolutionized the ginning of all types of long-staple cotton throughout the world; Sea Island cotton was no exception. Except for the U.S., countries that gin long-staple cotton still use the McCarthy gin on both long-staple and fuzzy-seeded Upland cottons.

Roller ginning from 1840 through 1900 was confined to South Carolina, Georgia, and Florida where Sea Island cotton was grown (Martin et al., 1940; Porcher and Fick, 2005). Records are scarce and not much is known about the overall design of the roller ginning plants in the 1800s; Fig. 11 shows an 1885 sketch that appeared in *Frank Leslie's Popular Monthly* of a steam-powered roller gin. The sketch is not mechanically detailed, but it is likely that there were additional McCarthy gin stands operating in the roller ginnery (Porcher and Fick, 2005). What is apparent is that roller ginning in the late 1800s was labor intensive with little machinery besides a power source, gin stands, and bale press. Roller ginning continued in the Southeast U.S. with an annual average output of more than 90,000 bales through the two decades ending with 1917 (Martin et al., 1940). With the arrival of the boll weevil in the Southeast U.S., Sea Island production decreased from 50,000 bales in 1918 to commercial production ceasing after 1923 and with it the need for roller gins. Except for a brief attempt to bring back Sea Island in the Southeast U.S. in the late 1930s that failed in the 1940s, roller ginning was finished in the southeastern U.S.

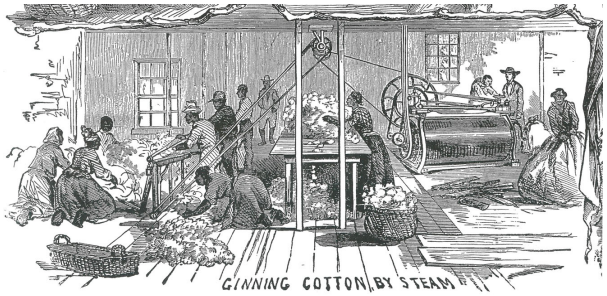

Figure 11. 1880s roller ginning system (taken from The Story of Sea Island Cotton by Richard Dwight Porcher and Sarah Fick).

During the time frame that Sea Island cotton production was decreasing in the Southeast U.S. due to the boll weevil and other factors, long-staple cotton production was being developed in the southwestern U.S. The USDA-ARS had been developing Egyptian-type ELS cotton varieties for the Southwest in the Yuma, AZ area starting in approximately 1902 (McGowan, 1961). Three-hundred seventy-five bales of the first commercial ELS American-Egyptian cotton variety (Yuma) was grown commercially in 1912 in Salt River Valley, AZ and Imperial County, CA. By 1920 the ELS American-Egyptian cotton plantings, now known more commonly as Pima cotton (in honor of the Pima Indians who grew the cotton for the USDA ELS breeding program), had reached 200,000 acres in Arizona and 43,000 acres in California. All this cotton had to be roller ginned as it was established early on that saw ginning added excessive neps and did too much fiber-length damage to ELS Pima cottons (Alberson and Stedronsky, 1964). Many of the roller gins

that had been idled in the Southeast due to boll weevil infestation found their way to the Southwest and were used to gin extra-long-staple Pima cotton. These early ginning systems in the Southwest included, in addition to the McCarthy single-roller reciprocating-knife roller gin stands, pneumatically fed seed cotton cleaners and shakers, and a simple cleaner-feeder with a spiked belt that fed the hand-picked seed cotton to the gin stand. The ginned fiber was then typically manually pushed to a single-box press for baling. As the gin stand in these early southwestern gin plants began to wear out in the 1920s and 1930s, they were replaced by newer manufactured gin stands but, as they were still ginning hand-picked cotton, the overall roller ginning system changed little from the early days until the advent of mechanical harvesting after World War II.

In 1952, several new roller gin plants were created in Arizona, New Mexico, and Texas to handle both hand- and machine-picked cotton (Alberson and Stedronsky, 1964). The roller-gin stands were reciprocating-knife roller gins, but machinery arrangements and other auxiliary equipment were similar to saw-gin plants of the time. By the time these gins were built, manual handling was replaced by suction systems to move seed cotton and ginned lint throughout the ginnery. As machine harvesting of Pima cotton replaced hand harvesting, battery mill-type lint cleaners (Fig. 12) were added between the reciprocating-knife roller gin stands and the bale press to help remove additional cotton trash brought in from the field by the harvester.

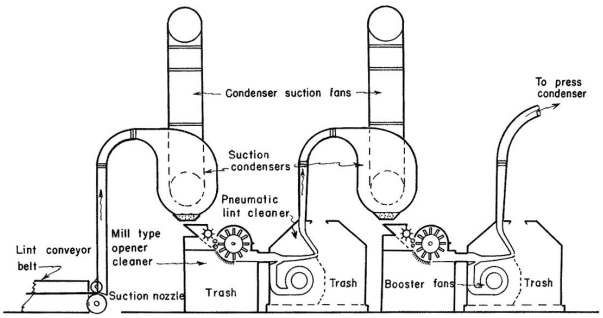

Figure 12. Pima lint cleaning system (taken from Modified Saw-Type Lint Cleaner for Roller Gins by I. W. Kirk and C. G. Leonard).

By 1963, the rotary-knife roller gin (Fig. 13) had been developed by efforts of the USDA-ARS Southwestern Cotton Ginning Research Laboratory, gin equipment manufacturers, and private roller ginneries (Gillum, 1985). This new roller-gin design could gin Pima cotton at one bale [218 kg (480 lb)] per hour, which was five times the rate of the latest version reciprocating-knife roller gin with equivalent fiber properties of the slower ginning method. The rotary-knife roller gin started replacing the reciprocating-knife roller gin in commercial gins and by 1980 the last commercial reciprocating-knife roller gin plant in the U.S. ceased operations. Further improvements to the rotary-knife roller gin included developing computer feed control (Gillum and Armijo, 1991), which enabled the roller ginning rate to be further increased. The next generation roller-gin stand was the high-speed roller gin design (also developed at the USDA-ARS Southwestern Cotton Ginning Research Laboratory), which had increased production rates of Pima and Upland cottons but with improved fiber nep and length qualities relative to saw ginning (Armijo and Gillum, 2007). The first high-speed rotary-knife roller gin installed in a commercial ginning plant in 2005 ginned Pima cottons four-times faster and Upland cottons three-times faster than on a conventional rotary-knife roller gin (Armijo and Gillum, 2010). Between 2005 and 2009 there were a total of 73 high-speed rotary-knife roller gin stands put into commercial operation, primarily in California, to gin both Pima and Upland cottons. By 2011 there were 188,000 bales of roller-ginned Upland cotton ginned in California for a reported premium of 13 to 26 ¢/kg (6-12 ¢/lb) paid by textile mills (Armijo et al., 2013). The seed cotton pre-cleaning of these modern roller ginning systems (either conventional or high speed) is similar to saw ginning systems, but the lint cleaners are pneumatic, cylinder-type, and textile-type rather than the saw-type typically used in saw ginning systems (Fig. 14).

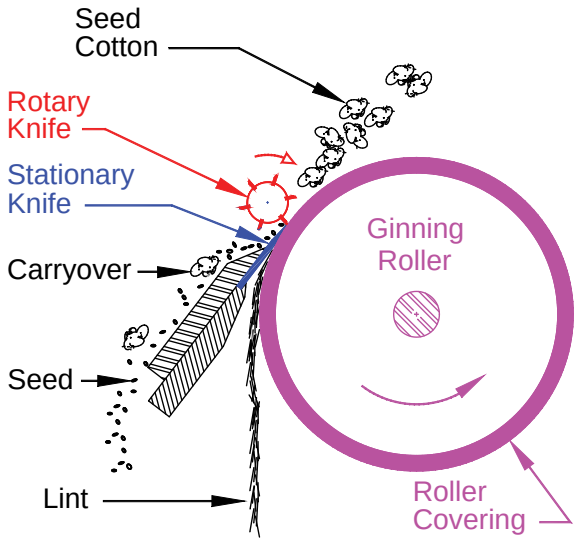

Figure 13. Rotary-knife roller gin (courtesy of USDA-ARS Southwestern Cotton Ginning Research Laboratory).

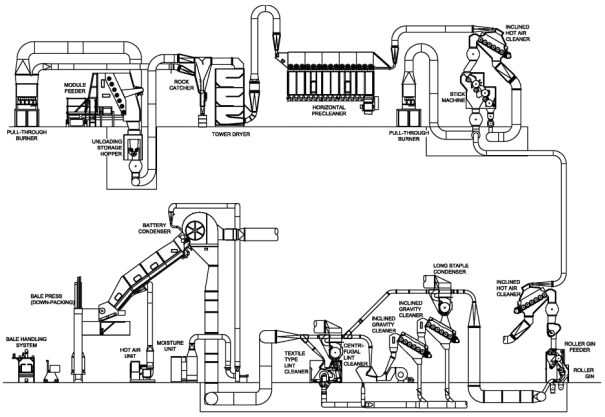

Figure 14. Typical current roller ginning system (courtesy of Ross Rutherford, Lummus Corporation).

COTTON PRODUCTION

Table 1 gives a sampling of cotton ginning statistics from 1900 through 2018. U.S. cotton production numbers through the 20th century and into the 21st initially show increases in cotton production as cotton moved to the West. Later production numbers show the impact of market price with the peak cotton production occurring in 2005 and later dropping off due to lower prices. The table also shows the steady decrease in the number of cotton gins and their increased ginning capacity due to long-term changes in cotton production practices, increased labor costs, and technical and mechanical innovation in response to and part of an evolving industry.

In the 21st century the U.S. cotton production and ginning systems will need to be more efficient with higher yields and improved fiber quality to continue being the important textile fiber it is today (Hughs et al., 2010). Cotton ginning will continue to evolve as part of the U.S. cotton production system.

DISCLAIMER

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture. USDA is an equal opportunity provider and employer.

REFERENCES

Alberson, D.M., and V.L. Stedronsky. 1964. Roller ginning American-Egyptian cotton in the Southwest. USDA Agriculture Handbook No. 257. U.S. Government Printing Office, Washington, D.C.

Anthony, W.S., and W.D. Mayfield. 1994. Development of the cotton gin. p. 1–6 *In* Cotton Ginners Handbook. USDA Agriculture Handbook 503. USDA, Washington, D.C.

Armijo, C.B., and M.N. Gillum. 2007. High-speed roller ginning of upland cotton. Appl. Eng. Agric. 23(2):137–143.

Armijo, C.B., and M.N. Gillum. 2010. Conventional and high-speed roller ginning of upland cotton in commercial gins. Appl. Eng. Agric. 26(1)5–10.

Table 1. Cotton Ginning Statistics

Year	U.S. Production Running Bales (1000's)	Number of Gins	Average Bales Ginned per Gin
1900	9,345	29,214	320
1910	11,609	26,234	443
1920	13,429	18,440	728
1930	13,932	14,494	961
1940	12,261	11,650	1,052
1950	9,848	7,650	1,301
1960	14,170	5,395	2,627
1970	10,112	3,750	2,697
1980	10,826	2,254	4,803
1990	15,065	1,533	9,827
1995	16,932	1,275	13,280
2000	16,742	1,018	16,446
2005	23,253	891	26,098
2010	17,643	700	25,204
2015	12,529	560	22,373
2017	20,441	553	36,964
2018	17,909	532	33,664

(Courtesy of National Cotton Ginners Association, Cordova, TN)

Armijo, C.B., J.A. Foulk, D.P. Whitelock, S.E. Hughs, G.A. Holt, and M.N. Gillum. 2013. Fiber and yarn properties from high-speed roller ginning of upland cotton. Appl. Eng. Agric. 29(4):461–471.

Bennet, C.A. 1957. Saw and toothed cotton ginning developments. The Texas Cotton Ginners Association, Dallas, TX.

Bennett, C.A. 1960. Roller Cotton Ginning Developments. The Texas Cotton Ginners Association, Dallas, TX.

Bennett, C.A. 1962. Cotton Ginning Systems and Auxiliary Developments. Texas Cotton Ginners' Association and Cotton Gin and Oil Mill Press, Dallas, TX.

Bennett, C.A., and F.L. Gerdes. 1935. Ginning Cotton. U. S. Department of Agriculture Farmers Bull. No. 1748. U.S. Government Printing Office, Washington, D. C.

Buchele, W.F., and W.D. Mayfield. 2016. Who really invented the cotton gin: unraveling the mystery and folklore of a critical agricultural innovation? Buchele Associates, LTD, Charleston, SC.

Giband, M., D. Dessauw, and P.A.V. Barroso. 2010. Chapter 1. Cotton: Taxonomy, origin, and domestication. *In* P.J. Wakelyn and M.R. Chaudhry (eds.), Cotton: Technology for the 21st Century. International Cotton Advisory Committee, Washington, D.C.

Gillum, M.N. 1985. High speed roller ginning. Trans. ASAE. 28(3):959–968.

Gillum, M.N., and C.B. Armijo. 1991. Computer-aided roller ginning. Trans. ASAE. 34(2):529–533.

Hughs, E., and G. Holt. 2015. Ginning. p. 609–664 *In* D.D. Fang and R.G. Percy (eds.), Cotton 2nd Ed., Agronomy Monograph 57. American Society of Agronomy, Inc., Crop Science Society of America, Inc., and the Soil Science Society of America, Inc., Madison, WI.

Hughs, S.E., C.B. Parnell, and P.J. Wakelyn. 2010. Cotton harvesting and ginning in the 21st century. *In* P.J. Wakelyn and M.R. Chaudhry (eds.),: Cotton: Technology for the 21st Century. International Cotton Advisory Committee, Washington D.C.

Hughs, S.E., T.D. Valco, and J.R. Williford. 2008. 100 years of cotton production, harvesting, and ginning systems engineering: 1907-2007. Trans. ASABE. 51(4):1187–1198.

Lakwete, A. 2003. Inventing the Cotton Gin—Machine and Myth in Antebellum America. Johns Hopkins Univ. Press, Baltimore, MD.

Lyengar, R.N. 1954. A method for the determination of the strength of attachment of the fibers to the seed and its effects on the ginning behavior of different cottons. Indian Cotton Growing Rev. 8:8–26.

Martin, W.J., J.S. Townsend, and T.C. Walton. 1940. Sea-Island cotton quality and ginning. USDA, Agricultural Marketing Service, Bureau of Plant Industry, and Bureau of Agricultural Chemistry and Engineering, Washington, D.C.

May, O.L., and K.E. Lege. 1999. Development of the world cotton industry. *In* C.W. Smith and J.T. Cothern (eds.), Cotton: Origin, History, Technology, and Production. John J. Wiley & Sons, Hoboken, NJ.

Mayfield, W., R.V. Baker, S.E. Hughs, and W.S. Anthony. 1991. Introduction to a Cotton Gin. National Cotton Ginners Association, Memphis, TN.

McGowan, J.C. 1961. History of extra-long staple cottons. M.S. thesis. Univ. Arizona, Phoenix.

Mirsky, J., and A. Nevins. 1952. The World of Eli Whitney. The Macmillan Company, New York, NY.

Moore, V.P. 1977. Development of the saw gin. p. 1-3. *In* Cotton Ginners Handbook, USDA Agricultural Handbook. 503. U.S. Gov. Print. Office, Washington, D.C.

Moore, V.P., and C.M. Merkel. 1953. Cleaning cotton at gins and methods for improvement. USDA Circular 922. U.S. Gov. Print. Office, Washington, D.C.

Porcher, R.D., and S. Fick. 2005. The Story of Sea Island Cotton. Wyrick & Company, Layton, UT.

Smith, C.W., R.G. Cantrell, H.S. Moser, and S.R. Oakley. 1999. History of cultivar development in the United States. *In* C.W. Smith and J.T. Cothern (eds.), Cotton: Origin, History, Technology, and Production. John J Wiley & Sons, Hoboken, NJ.

Vandergriff, A.L. 1997. Cotton Ginning: An Entrepreneur's Story. Texas Tech Univ. Press, Lubbock, TX.